

FIELD OF THE INVENTION

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BACKGROUND OF THE INVENTION

In the present state of the art, various optical networking service models are available. The optical networking models serve different types of users including trusted and untrusted users and provide a variety of optical services. These optical networking models include: (1) an overlay model as shown in Figure 1(A); (2) a peer to peer model as shown in Figure 1(B); and (3) an augmented model as shown in Figure 1(C).

As shown in Figure 1(A), in the overlay model, an optical domain 10a is separated from another service layer domain such as the IP routing domain 10b. The IP routing domain 10b is a client layer of the optical domain 10a while the optical domain 10a is a server layer to provide light

path services for the IP layer through an optical User-to-
Network Interface (UNI) 10c. Generally, the overlay model
is for the untrusted user. No optical routes are disclosed
to the user. Optical service providers own all optical
5 resources. IP routing is independent from the optical
networks. User signal bandwidth and protection are offered
via the UNI signaling protocol.

The peer-to-peer model, as shown in Figure 1(B) is
appropriate for the trusted user. User signal bandwidth and
10 protection are available via an extended Internet protocol.

The trusted user owns some or all of the optical resources
via a unified IP/optical routing protocol. In the peer-to-
peer model, the IP domain 11a and the optical domain 11b are
on the same level and communicate over an optical Network-
15 to-Network Interface (O-NNI) 11c. IP routers typically
treat optical switches as another type of router. Thus the
IP domain 11a and optical domain 11b can exchange routing
information seamlessly.

The augmented model shown in Figure 1(C) is also for
20 the trusted user. In the augmented model, the IP layer acts
as a peer of the optical layer network, such that a single
protocol instance runs over both the IP domain and the

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SUMMARY OF THE INVENTION

According to the present invention, a technique for efficiently partitioning and managing overall network resources in an efficient and cost effective manner is
5 provided.

In one embodiment, the technique is realized by a method for routing information over an optical network having multiple optical service models. The method comprises receiving a link state advertisement at a switch; checking
10 flooding domain information to decide whether to broadcast or block propagation of the link state advertisement, wherein checking the flooding domain information comprises checking an optical UNI interface type, an optical interface descriptor, and available bandwidth; and accepting or
15 rejecting the request based on the flooding domain information.

In accordance with other aspects of the present invention, a method is provided for routing information over an optical network having multiple optical service models.
20 The method comprises receiving a link state advertisement including an incoming optical interface descriptor at an optical switch; checking outgoing link information; flooding

the link state advertisement over the outgoing link if the outgoing link information includes a first pre-defined value; blocking the link state advertisement if the outgoing link information includes a second pre-defined value; and
5 comparing the incoming optical interface descriptor with the outgoing link information if the outgoing link information includes neither the first pre-defined value nor the second predefined value and flooding the link state advertisement only if the incoming optical interface descriptor and the
10 outgoing link information include matching values.

In accordance with still further aspects of the present invention, a system is provided for routing information over an optical network having multiple optical service models. The system comprises wavelength routing protocol means for
15 flooding a link state advertisement to an optical switch; means for checking an optical interface descriptor and outgoing link information to determine whether to broadcast or block propagation of the link state advertisement; and wavelength distribution protocol means for issuing a
20 connection request upon receiving a broadcast determination.

The present invention will now be described in more detail with reference to exemplary embodiments thereof as

shown in the appended drawings. While the present invention is described below with reference to preferred embodiments, it should be understood that the present invention is not limited thereto. Those of ordinary skill in the art having access to the teachings herein will recognize additional implementations, modifications, and embodiments, as well as other fields of use, which are within the scope of the present invention as disclosed and claimed herein, and with respect to which the present invention could be of significant utility.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to facilitate a fuller understanding of the present invention, reference is now made to the appended drawings. These drawings should not be construed as limiting the present invention, but are intended to be exemplary only.

Figures 1(A)-1(C) are block diagrams illustrating three service models known in the art;

Figure 2 is a flow chart illustrating the operation of optical intelligent protocols;

Figure 3 is a block diagram illustrating a system for implementing flooding restrictions of the invention;

Figure 4 is a block diagram showing details of a service provider domain and a user domain;

5 Figure 5 is a block diagram illustrating details of the control configuration;

Figure 6 is a block diagram illustrating system control architecture for an optical switch;

10 Figure 7 is a block diagram illustrating a system control configuration;

Figure 8 is a chart showing the contents of the optical interface descriptor, Service LSA, and administrative domain;

15 Figure 9 is a flow chart illustrating optical and service LSA propagation;

Figure 10 is a flow chart showing routing of optical and service LSAs;

Figure 11 is a flow chart illustrating control message signaling;

20 Figure 12 illustrates an embodiment of an optical network with user routing domain partitioning;

Figure 13 is a flow chart illustrating a method of LSA propagation;

Figure 14 is a flow chart illustrating an additional method of LSA propagation;

5 Figure 15 is a chart showing proposed flooding restrictions;

Figure 16 illustrates an embodiment of an UNI login graphic user interface (GUI);

Figure 17 illustrates a UNI main GUI;

10 Figure 18 illustrates an embodiment of a UNI property GUI;

Figure 19 illustrates an embodiment of a UNI Register/De-Register GUI;

15 Figure 20 illustrates an embodiment of a UNI connect/disconnect GUI;

Figure 21 illustrates an embodiment of a UNI modify lightpath GUI; and

Figure 22 illustrates an embodiment of a query light path GUI.

20 **DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENT(S)**

Referring to Figure 1(A)-1(C), three existing service models are shown. All of these three service models are

supported by the system of the invention. Each of the three models, including the overlay model of Figure 1(A), the peer to peer model of Figure 1(B), and the augmented model of Figure 1(C) is described above in the Background of the

5 Invention.

Figure 2 is a block diagram illustrating the operation of several different optical intelligent protocols 1a-1c operating on a plurality of networks 2 which are connected by optical network-to-network interfaces (O-NNIs)3. The
10 networks 2 are connected with users 4 through optical user-to-network interfaces (O-UNIs) 5. Wavelength routing protocol (WRP) and wavelength distribution protocol (WDP) 1a control routing and distribution between the networks 2 over the NNIs 3. Optical bandwidth control protocol (OBCP) 1b
15 controls exchanges between a user 4 and a network 2 over an O-UNI 5. Optical link management protocol (OLMP) operates between the networks 2. In summary, WRP and WDP perform routing and signaling functions. OBCP provides O-UNI services, and OLMP provides link management and fault
20 isolation.

Each of the above-described protocols serves multiple functions in the system of the invention. WRP performs

optical topology discovery and inventory of physical
resources. WRP further locates available or reserved
resource advertisements and performs optical bandwidth
grouping at various channel granularities. WRP is the
5 primary protocol for O-UNI interworking and control
integration. WRP is responsible for channel/link pre-
authorization advertisement. Another primary function of
WRP is to execute new path selection using an optimization
algorithm to support traffic engineering and constraint
10 based routing. WRP ensures that all interfaces are IP
addressable and secures integrated protection/restoration.

WDP provides a classified label for connection type and
bandwidth. WDP further enables end-to-end signing for
setup, tear-down, and modification of optical paths. WDP is
15 further responsible for ensuring optical traffic/interface
compatibility, bandwidth assignment for optical switches,
and path priority assignment for protection and traffic
engineering.

OBCP has various service functions including O-UNI
20 registration/de-registration, connection request and
release, bandwidth modification service status inquiry,
service signaling and protection, and neighbor discovery and

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service discovery. OBCP further provides optical augment routing, third party signaling and service scheduling, O-VPN services, service policy enforcement, and service billing.

Finally, OLMP facilitates neighbor discovery, link type
5 identification, wavelength scope identification and negotiation, and link bundling. OLMP further provides control channel management and protection, component link verification, fault detection, and fault isolation.

Figure 3 illustrates a system for implementing an
10 optical user-to-network interface (O-UNI) client-server distributed architecture. An O-UNI server 100, a client 200, and a management system 300 are connected over a control network 400. A multiplexer 500, a router 600, and a switch 700 are connected to the network 400 and to the
15 management system 300 via two types of physical connections. One is a control access link to exchange control information. One is a data access link for payload traffic.

An O-UNI is registered by an optical bandwidth control protocol (OBCP) 310. The OBCP 310 manages connection
20 requests, bandwidth changes, service status inquiries, service signaling and protection, and neighbor discovery and service discovery. The OBCP 310 also manages optical

augment routing, third party signaling and scheduling services, O-VPN services, service policy enforcement, and service billing.

Figure 4 is a block diagram showing an O-UNI reference
5 model. A service provider domain 100 communicates with user domains 200 over the O-UNI 5. The service provider domain 100 includes a connection control plane 110 and an optical transport network 120 connected over an NNI 3. The service provider domain 100 and the user domain 200 conduct
10 signaling over a first UNI path 5a between the user 200 and the connection control plane 110 and conduct transport over a second UNI path 5b between the user 100 and the optical transport network 120.

Figure 5 is a block diagram showing control blocks
15 and an application program interface (API) among WDP, WRP and the other protocols. Application Program Interface (API) is a set of routines, protocols and tools for building software applications. Core services include WDP 21, a data plane control interface 22, Generic Switch Management
20 Protocol (GSMP) 23, OLMP 24, WRP 25, and protection 26. Target services include a traffic engineering processor 41 and OBCP 42. Link, switch, and protection management

resources include link resource management information bases
(MIBs) 31, equipment resource MIBs 32, WDP and Traffic
Engineering (TE) MIBs 33, route manager 34 and route watch
35. An MIB is a database of objects that can be monitored
5 by a network management system. A label manager 72
functions through WDP 21.

Figure 6 illustrates system control architecture 51 for
an optical switch. Management interface protocol and WRP
protocol interact with route determination tools 51a, a
10 topology database 50b, and topology exchange 50c. O-UNI
signaling and WDP protocol provide services such as O-UNI
signaling 55a, call processing 55b, and WDP signaling 55c.
The control architecture 51 also includes tools for resource
management 60a, fault management tools 60b, x-connection
15 management tools 60c, protection management tools 60d, and
switch fabric 65.

Figure 7 illustrates an example of a system control
configuration. The service provider 100 implements OBCP
310, WRP/WDP 320, and OLMP 340 and includes a switch driver
20 330. A parallel cable 302 attaches to a switch card 305,
which is attached to a port card 308. The service provider
300 communicates with the Internet 400 through an Ethernet

315.

Figure 8 illustrates the mechanisms that the service provider 300 uses to constrain optical route flooding. An optical interface descriptor (OID) is attached to each optical LSA. The optical interface descriptor contains information relevant to each user group such as a user termination point 112, user group identifier 114, user contract ID 116, and user service mode 118. The service mode 118 is expressed as a Type Length Value (TLV) which in a preferred embodiment is a 32 bit integer component with a value between 1 and 3. The user service mode 118 has a different TLV for each of the modes described above such as the peer-to-peer mode, the overlay mode, and the augmented mode. A first value selected for the overlay model indicates that no route information is flooded into the user domain. A second value selected for the augmented model indicates that route information may be flooded into the user domain, and a third value for the peer-to-peer model indicates that all optical route information is flooded into the user domain. The OID is also represented by a TLV which is preferably a 32 bit integer. A value of 255.255.255.255 preferably indicates a broadcast group. A value of 0

preferably represents a disabled group. Other values represent specific user groups.

In addition to the OID, the mechanisms for constraining optical route flooding include an optical link

5 administrative domain 120. The administrative domain includes a link color 122, either a broadcast indicator 123a or a block indicator 123b, and an user group ID 125. If the propagating LSA is a service LSA 130, the service LSA 130 includes an expanded OID 132. The OID 132 additionally
10 includes a user service type 133, such as ATM or IP, a control protocol 134 such as Border Gateway Protocol (BGP) or Private Network Network Interface (PNNI), a framing protocol such as GE, OC-X, or fiber channel, and a link color 134.

15 Prior to connecting, an optical switch must check a user status TLV. The user status TLV is preferably a 32 bit integer having a value between 0 and 3. A first value indicates "out of service". A second value indicates "idle". A third value indicates "busy" and unavailable and
20 fourth value indicates "testing" and temporarily unavailable.

Figure 9 is a diagram showing the propagation of the

service LSA 70 over an O-UNI and the propagation of an
optical LSA 80 over an NNI between the links 2. In
operation, the WRP floods the service LSA 70 and the optical
LSA 80. Optical switches check the administrative domain to
5 determine whether it indicates that the LSA should be
broadcast or blocked. WDP issues a connection request and
checks the OID, the UNI interface type and available
bandwidth. If the appropriate criteria are met, the request
will be accepted. Otherwise, the request will be denied.

10 Figure 10 illustrates control message routing. As
shown in section A, a service LSA 70 is propagated over a
UNI A from a multiplexer (MUX) 68 to a first switch 71.
Both an optical LSA and a service LSA are propagated over an
NNI B between the switches 71 and 72. The service LSA is
15 propagated from the switch 72 over a UNI C to an OPC 73.

Figure 11 is a signaling flow chart showing UNI connect
signaling 81 from the MUX 68 over the UNI A to the switch
71. WDP connect signaling 82 is sent from the switch 71
over the NNI B to the switch 72. The switch 72 sends UNI
20 connect signaling 83 over the UNI C to OPC 73. OPC 73 sends
UNI confirm signaling 84 over the UNI C to switch 72. The
switch 72 sends WDP lapel mapping signaling 85 over the NNI

B to the switch 71 and the switch 71 sends UNI confirm signaling 86 over the UNI A to the MUX 68.

Figure 12 shows an optical network 7 with user routing domain partitioning. Links 8a belong to a first color group, links 8b are broadcast links, links 8c belong to a second color group, and links 8d belong to a third color group. Edge Device (ED) 12a represents a first color group and ED 10d represents a second color group. As shown, restrictive flooding is conducted over the links 8a-8d.

10 Restrictive flooding is performed both over the UNI and the NNI.

Figure 13 is a flow chart showing a first embodiment of the method of the invention using WDP and WRP. In step A10, the system configures the O-UNI and the O-NNI for each link.

15 In step A20, WRP floods both a service LSA and an Optical LSA. In step A30, optical switches check the flooding domain to determine whether to broadcast or block the propagation. If in step A35, the system determines that the LSA should not be broadcast, it blocks the propagation in

20 step A37. If in step A35, the system determines that it should broadcast the propagation, WRP further checks if the flooding domain, user group and link color match with the

information contained in the LSA, in step A40. If all these parameters are matched. WRP will flood the LSA to user device in step A45. If they are not matched. WRP will block this flooding.

5 The comparison in step A40 is performed as follows.

Upon receiving an LSA, an optical switch checks the information attached to the LSA. The specific information that is attached to an LSA depends upon the type of LSA. Assuming the LSA is an optical LSA, the switch checks the
10 information for each possible (outgoing) link to determine if the LSA should be flooded over that link. In the embodiment explained above, if the outgoing link OID is 255.255.255.255, the switch floods the LSA. If the outgoing link OID is 0, the switch does not flood the LSA over the
15 link. If the outgoing OID is another value, the switch compares the incoming OID to the outgoing OID. If the values match, the switch floods the LSA. If the values do not match, the switch does not flood the LSA.

The above-described technique may be used with open
20 shortest path first. Open Shortest Path First (OSPF), is a routing protocol developed for IP networks based on the shortest path first or link-state algorithm. Routers use

link-state algorithms to send routing information to all
nodes in an internetwork by calculating the shortest path to
each node based on a topography of the internet constructed
by each node. Each router sends that portion of the routing
5 table that describes the state of its own links and it also
sends the complete routing structure or topography. If
using OSPF, the optical switch will compare the OID of an
incoming LSA with the link information or OID for all
outgoing links to determine which link should be flooded.

10 Figure 14 illustrates a second embodiment of optical
LSA and service LSA propagation using WRP, WDP, and OBCP.
In step B10, the WRP and WDP configure the NNI for each
optical link. In step B20, WRP floods the optical LSA and
exchange topology for the routing database. In step B30,
15 the OBCP configures the O-UNI for each service access link.

In step B40, OBCP floods the service LSA. In step B50,
optical switches check the flooding domain to decide whether
to broadcast or block the propagation of the service LSA to
another OBCP server. If it is determined in step B55, that
20 the LSA should not be broadcast, the LSA is blocked in step
B57. If in step B55, it is determined that the LSA should
propagate, the OBCP server accepts the service LSA and

stores this information in its database. The OBCP server may distribute this information to the according user devices via O-UNI proxy agents in step B57. On the other hand, the O-UNI proxy in step B60 will accept the connection request from user devices and conducts address resolution and forwards the request to WDP. In step B70, WDP consults with WRP to get a constraint based path. The constraint based path can be determined from the routing database accessed in step B20. In step B80, WDP issues a connection request with and checks the UNI interface type, OID, and available bandwidth. This check is performed substantially as described above with reference to Figure 13. Based on the results of the check in step B85, the connection may be made in step B90.

Figure 15 is a chart illustrating an embodiment of the flooding restrictions for each of the three above-mentioned service models. The service models are listed in column A and the LSA types including the service LSA, the optical LSA, and other LSAs are listed in the first row. Cell A0 represents other service modes. As shown in cells, B0, C0, and D0, the LSAs are blocked for service modes which are not supported by the system of the invention. Cell A1

represents the overlay mode. In the overlay mode, service LSAs are flooded as shown in B1, while optical and other LSAs are blocked as shown in C1 and D1. Cell A2 represents the augmented mode. In the augmented mode, both service
5 LSAs and optical LSAs are flooded as shown in B2 and C2. However, other LSAs are blocked as shown in D2. The Peer-to-Peer model is represented in cell A3. In the peer-to-peer model, all LSAs are flooded as shown in B3, C3, and D3.

From the standpoint of the user, the UNI login graphic
10 user interface (GUI) is shown in Figure 16. The login GUI 500 includes a user name entry blank 501, a password entry blank 502, a UNI server blank 503, an OK button 504, and a cancel button 505.

From a system perspective, a UNI main GUI 510 is shown
15 in Figure 17. The users such as Mike at 200a and user n at 200b are connected through the above-described optical components 600. The main GUI displays a UNI property 520, a register/de-register option 530, a connect/disconnect option 540, a modify lightpath option 560, and a query lightpath
20 option 580.

The UNI property GUI is shown in Figure 18. The GUI 520 includes information such as user ID 521, user group

522, node address 523, port ID 524, channel ID, 525,
subchannel ID 526, contract ID 527, directionality 528,
service type 529, and bandwidth 530. OK option 531 and
cancel option 532 are available.

5 For registration, the GUI 520 offers several more
options shown in Figure 19. Specifically, the
directionality 528, the service type 529, and the bandwidth
530 are selectable. Registration option 533 and de-
registration option 534 are provided.

10 Figure 20 shows an embodiment of the UNI
connect/disconnect GUI 540. From a destination user ID 541,
the system locates the intended destination. The source
node 551 and the destination node 552 appear at the top of
the GUI 540. Bandwidth 542, protection level 543, link type
15 544, maximum delay 545, signaling type 552, starting time
546, and duration 547 are shown on the GUI 540. All
parameters except the starting time 546 and duration 547 are
selectable. On OK button 548 and a cancel button 549 are
provided.

20 Figure 21 shows a UNI modify lightpath GUI 560. The
lightpath ID 561 is entered. The source node 562 and
destination node 563 are shown. The GUI 560 also shows the

configured bandwidth 564 and the configured protection 565.

Selectable parameters include new bandwidth 566 and new protection 567. Options include an OK option 568 and a cancel option 569.

5 Figure 22 shows a query lightpath GUI 580. The
lightpath ID 581 is identified. The GUI 580 also identifies
a source node 582 and a destination node 583. The
parameters displayed include bandwidth 584, protection 585,
link type 586, maximum delay 587, signaling type 588,
10 connected time 589, starting time 590, and duration 591.
The signaling type 588 is selectable. An OK button 592 and
a cancel button 593 are provided.

 The management system provides a hybrid optical service
model that uses user-domain constrained optical route
15 flooding to support multiple service models. The optical
interface descriptor (OID) is defined to restrict the
flooding domain. An optical LSA and a service LSA propagate
the OID. The system adds value to Internet Engineering Task
Force (IETF) and OIF standard activities.

20 The management structure includes multiple identifiers
for determining route flooding procedures. An optical
interface descriptor (OID) includes information such as a

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that its usefulness is not limited thereto and that the
present invention can be beneficially implemented in any
number of environments for any number of purposes.
Accordingly, the claims set forth below should be construed
5 in view of the full breadth and spirit of the present
invention as disclosed herein.

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